Transect Orientation Model (TRANSORI) for the Park Units in the Northern Colorado Plateau Network

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Introduction

Monitoring a suite of vital signs associated with upland ecosystems is a key component of the Northern Colorado Plateau Network (NCPN) Inventory and Monitoring program. Upland monitoring plots will consist of three parallel transects 50-m long, and spaced 25-m apart. The coordinates of the centroid of an upland monitoring plot will be selected from a sampling frame. Procedures for this selection are described elsewhere. The parallel transects are to be centered on this centroid, but for various reasons, oriented parallel to the contour.

Estimating the coordinates of the end-points of transects oriented parallel to the contour is useful for two reasons. GIS mapping of plot transects will be a critical first step to evaluating the suitability of a selected plot. Plots with transects extending into areas otherwise excluded from monitoring can be readily eliminated from consideration. Additionally, during initial plot set-up, the field crew can use the list of end-point coordinates to navigate to plot center while minimizing trampling on otherwise unmarked transects.

The NCPN developed a customized model that relies on GIS-derived raster layers of slope and aspect to derive UTM coordinates of transect end-points given a centroid coordinate and parallel-to-contour transect orientation. The model, called TRANSORI (Transect Orientation), is coded in C and runs on standard PC computers. This document describes the basic features of the TRANSORI model, including input requirements, calculations, and output, and the syntax for running the model.

Data Requirements

TRANSORI uses a list of transect centroids, and slope and aspect spatial data layers to derive end-point coordinates of transects. Transect centroids are an ASCII-formatted list of UTM coordinates. Spatial data layers are grid-based, and in ArcGIS ASCII format. The two grids (s.l. data layers) must have the same grain size. A 10-m spatial grain typically is used for the NCPN. This grain size is a reasonable compromise between accuracy file size. Finer grain sizes substantially increases file size, and unnecessarily adds to processing time. An additional requirement is that all data layers must be of the same geo-registration and spatial extent; that is, they must have the same number of rows and columns and coordinate system.

Input Data

The required spatial data layers are listed below along with expected values. Background is other than the indicated values:

> slope_layer – percent slope ($\geq$ 0)
> aspect_layer – degrees (-1 for flat; else 0-360).

Spatial data layers must be in ArcGIS ASCII format. ArcGIS files are converted from a coverage to ASCII with the gridascii Arc command. Data layers can be of any data type. However, TRANSORI internally converts input values to short integers (i.e., 16-bit number).

The centroid file is a ASCII-formatted list of UTM coordinates with two associated, integer plot identifiers. The identifiers link a centroid to databases associated with the sampling frame. The current format of the centroid file is:

identifier1, identifier2, UTMN, UTME

where;

identifier1 and identifier2 are integer values associated with transect order (set in the sample-site selection procedure) and the FID (Feature ID),

UTMN and UTME are northing and easting UTM coordinates, respectively, of the center of the sampling plot (centroid of the middle transect).

Overview of Calculations

Derivation of transect end-points involves a three step process. First, the average direction of the slope for the plot is determined using vector averaging. The vector-averaging procedure uses the aspect and the fractional slope of cells within a user-specified area around the plot centroid to derive a representative down-hill slope azimuth of the plot. The area interrogated in the vector-averaging procedure must be large enough to contain the three transects at any orientation. This area is termed the search window, and is square. For 50-m transects, a 100 - 120-m search window (1-1.44 ha) is sufficient. In essence, a plot centroid is overlaid on the spatial data layers, and the user-specified, one-sided length of the search window delineates the data-layer cells included in the vector-averaging procedure. Second, the azimuth perpendicular to the average slope azimuth is determined, and corresponds to the orientation of the three parallel transects (i.e., the longitudinal axis of a transect). Third, the derived transect orientation along with user-provided transect length and inter-transect distance are used to derive the UTM coordinates of transect end-points. UTM coordinates of the centroid, and the calculated transect end-points are output along with measures of transect orientation, and the input plot identifiers which provide a link to the sampling frame. The output coordinates can be imported to ArcGIS and mapped, and imported to GPS units to aid in navigation in the field.

Vector Averaging

Basic trigonometric methods are employed to derive an average slope azimuth, with aspect corresponding to the angle and fractional slope corresponding to the hypotenuse of a right triangle. The vertical (i.e., rise) and the horizontal (i.e., run) components of a right triangle are calculated for each cell in the search window, and are summed separately. The ArcTan of the ratio of the average rise and average run gives an average slope azimuth. The vertical (rise) and horizontal (run) components are derived by:

$$\text{rise} = \sin(\text{aspect}) * \text{fractional\_slope} \quad (1)$$

$$\text{run} = \cos(\text{aspect}) * \text{fractional\_slope} \quad (2)$$

where;

aspect is in degrees.

The general formula for deriving average azimuth of the slope is:

$$\text{az} = \text{ATan}\left(\Sigma(\text{rise})/n \ / \ \Sigma(\text{run})/n\right) \quad (3)$$

where;

n is the number of cells,

ATan is ArcTangent,

az is the average azimuth of the slope (i.e., down-slope direction).

Equations 1- 3 are used to derive a mean slope azimuth for quadrant pairs - 1 & 2, 3 & 4. For the later condition, az (eq. 3) is transformed by 180 degrees. For both pairs of quadrants, az is scaled from 1 to 360 degrees.

The plot level average slope azimuth is a weighted average of az (eq. 3) for the two pairs of quadrants, with the proportion of total fractional slope as the weight:

$$\text{azimuth} = (\text{az}_i * \text{pslope}_i) + \text{az}_j * \text{pslope}_j) \quad (4)$$

where;

i, j indicate quadrant pairs (1&2, 3&4),

pslope is the proportion of total fractional slope (sum of fractional slope across all cells in the search window),

az is from equation 3.

Derivation of Transect End-Points

The center of each transect is used to determine the coordinates of the end points. The center coordinates of the middle transect is the plot centroid which is provided in the centroid input file. The center coordinates of the up-hill and down-hill transects are derived by:

$$Centroid\_E = (inter\_tran\_distance * \sin(azimuth + x)) + UTME \tag{5}$$
$$Centroid\_N = (inter\_tran\_distance * \cos(azimuth + x)) + UTMN \tag{6}$$

where;

UTME and UTMN are the UTM coordinates of the user-provided plot centroid (i.e., the center coordinates of the middle transect),
x is a displacement, and equals 0 for the down-hill transect and 180 for the up-hill transect,
azimuth is from eq. 4,
inter_tran_distance is the user-provided inter-transect distance in meters,
Centroid_E is the easting UTM coordinate of the transect center,
Centroid_N is the northing UTM coordinate of the transect center.

Given the UTM coordinates of the center of a transect, the end points are derived by:

$$Left\_E = (transect\_length/2 * \sin(azimuth + 90)) + Centroid\_E \tag{7}$$
$$Left\_N = (transect\_length/2 * \cos(azimuth + 90)) + Centroid\_N \tag{8}$$

$$Right\_E = (transect\_length/2 * \sin(azimuth - 90)) + Centroid\_E \tag{9}$$
$$Right\_N = (transect\_length/2 * \cos(azimuth - 90)) + Centroid\_N \tag{10}$$

where;

Centroid_E and Centroid_N are from eqs. 5 and 6, respectively, for the down-hill and up-hill transects, or the user provided plot-centroid coordinates for the middle transect,
azimuth is from eq. 4,
transect_length is the user-provided length (meters) of a transect,
Left_E and Left_N are easting and northing UTM coordinates, respectively, of the transect end-point that is to the left relative to the upslope direction (Fig. 1),
Right_E and Right_N are easting and northing UTM coordinates, respectively, of the transect end-point that is to the right relative to the upslope direction (Fig. 1).

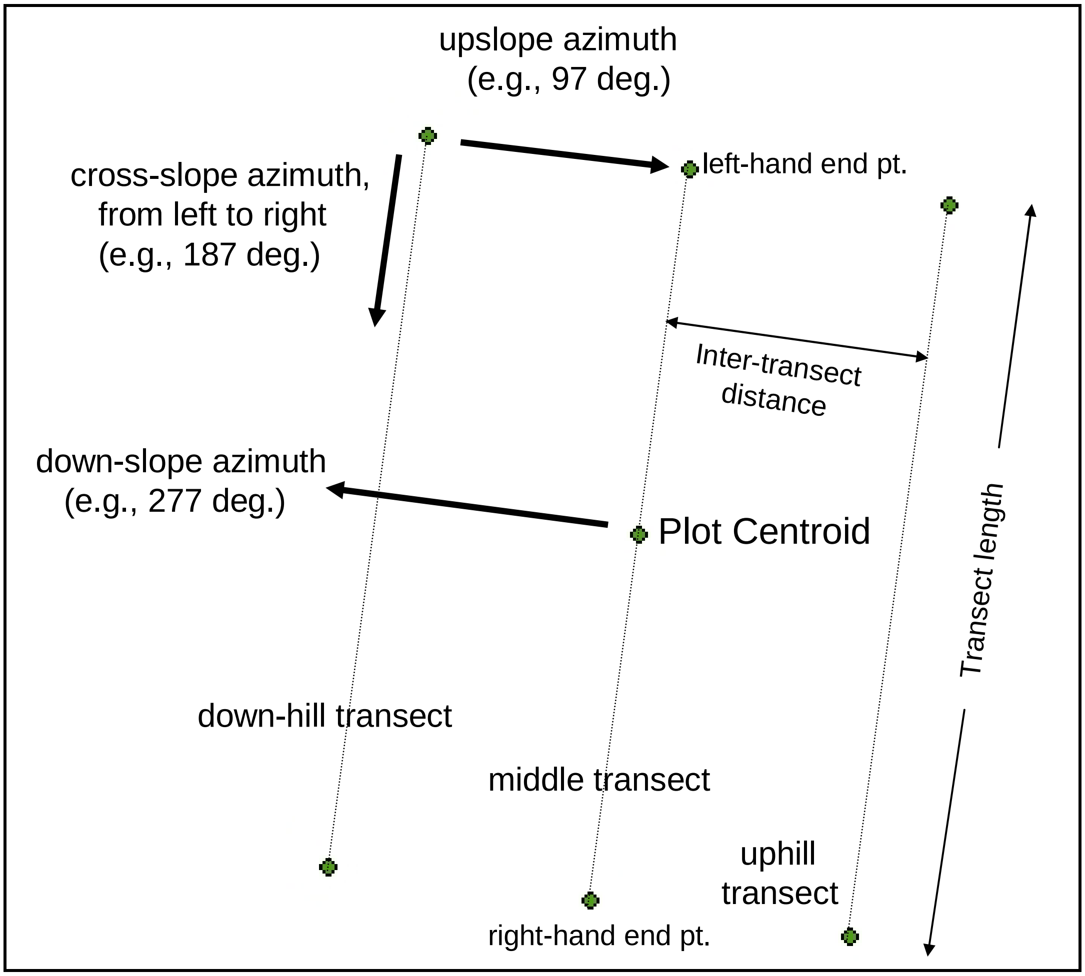

Figure 1. Illustration of terms used in TRANSORI.

Output

For each plot centroid, the following values are recorded in ASCII format:

- two plot identifiers,
- UTM coordinates (northing, easting) of the plot centroid,
- average slope azimuth (down-slope direction),
- azimuth perpendicular to the average slope azimuth (cross-slope azimuth, from left to right – Fig. 1.),
- upslope azimuth (average slope azimuth plus 180 degrees, Fig. 1).

In addition, the following values are recorded for the down-hill, the middle, and the up-hill transects:

- UTM coordinates (northing, easting) of the left-hand end-point,
- UTM coordinates (northing, easting) of the right-hand end-point.

Program Syntax

To operate TRANSORI, you must store the executable as transori.exe. To run the TRANSORI program, enter the following:

transori <aspect_layer> <slope_layer> <centroids> <search_window_m> <inter-transect_distance_m> <transect_length_m> <outputfile>

where;

<aspect_layer> is the name of the aspect grid (ArcGIS ASCII format),
<slope_layer> is the name of the percent-slope grid (ArcGIS ASCII format),
<centroids> is the name of the file containing the centroid coordinates (ASCII),
<search_window_m> is the one-sided length (meters) of a square area around the plot centroid used to derive the average aspect,
<inter-transect_distance_m> is the distance (meters) between adjacent transects,
<transect_length_m> is the length (meters) of a transect
<outputfile> is the name of the file to store the resulting end-point coordinates in ASCII format.

The number of rows and columns, and the spatial grain of the input data layers are read directly from the header fields. Number of rows and columns, and spatial grain are compared between the slope and aspect layers to determine consistency. If inconsistent, an error message is displayed on the screen and the program terminates.

The program transori.exe can reside anywhere on your computer, but an explicit path to the directory containing the program must be inserted via the PATH command to execute the program from any directory. Alternatively, the path can be specified in the command-line syntax. E.g., h:\transectdirectory\transori < > < > …

Memory Requirements

The spatial data layers are read into memory at program initiation. Memory-resident matrices used to store the data layers are responsible for much of the memory needs. Memory is dynamically allocated based on the number of rows and columns of the data layers. Thus, grids of any size can be processed without code changes. However, standard PC operating systems limit the amount of memory that can be allocated per process. This limit is currently 3 GB on MS-Windows and MS-XP operating systems. Memory-allocation checks are embedded in TRANSORI. If memory limits are exceeded, an error message is displayed and processing immediately terminates.

Memory requirements can be estimated with the following formula:

$$GB = ((2 * r * c) / 1024000000.0) + 0.1$$

where;

r is no. of rows,
c is no. of columns,
1024000000.0 converts from bytes to GB,
0.1 is an estimate of memory needs for other code components,
GB is the total memory requirement in GigaBytes.

Key Assumptions & Limitations

1) Credibility of the derived end points is directly related to the grain and quality of the slope and aspect layers. The user is responsible to ensure accurate and credible slope and aspect information.

2) The current version does not use slope-adjusted distance in deriving UTM coordinates of transect end-points. Thus, on steep slopes, the actual location of transect end-points will deviate from derived estimates. Estimates derived with this model are intended to guide GIS assessments and field navigation. Slope-adjusted coordinates may be included in future enhancements, if deemed necessary.

TRANSORI Revision History

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #